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A provisional checklist of European butterfly larval foodplants

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Abstract. Successful conservation of butterflies is dependent on knowing which larval foodplants they use. However, many published lists of larval foodplants have been copied from previous lists, which in turn have been copied from previous lists. Consequently, errors have crept in, and many plant names have long been superseded. This can result in duplicates in the list, with the same plant being given two different names. Most plant lists do not include the authority, which can make it difficult or impossible to identify which plant is being referred to. For the first time, a list of the current accepted plant names utilised by 471 European butterfly larvae is presented, with references. Where possible, errors in previous lists have been removed. The list of larval foodplants doubled from previous published lists. This has resulted in a list of 1506 different plant species in 72 different families. 86 plant records are only known at the generic level. Larval foodplants of 25 butterfly species are currently unknown. Whilst most plant families are utilised by less than six butterfly species, a few plant families are particularly favoured, with the Poaceae and Fabaceae being the most popular. Similarly, most plant species are only utilised by a few butterfly species, but *Festuca ovina* and *Festuca rubra* are favoured by a large number of butterfly species. 20% of European butterfly larvae are monophagous, 50% are oligophagous, and 30% are polyphagous, with *Celastrina argiolus* able to use plants in 19 different families.

Introduction

The conservation of butterflies requires an understanding of their resource requirements, particularly during the larval stage. Most butterfly species are not restricted to a single hostplant species, with geographic, site specific and seasonal differences in hostplant use. For example, *Celastrina argiolus* larvae (mainly) use *Ilex aquifolium* in the spring, and *Hedera helix* in the autumn (Tutt 1908). Many butterflies in the families Riodinidae and Lycaenidae have relationships with ants (Formicidae) to varying degrees, with butterflies in the genus *Phengaris* parasitic on ants in their later larval instars. Fiedler (2021) provides a list of the Lycaenidae butterflies with their associated ants, with references. Two species are known to switch their larval foodplant during their second year of development. *Euphydryas maturna* for example, switches from *Fraxinus excelsior* to *Viburnum opulus* (Eliasson et al. 2005). *Pyrgus centaureae* switches from *Betula nana* to *Rubus chamaemorus* (Wickman 2012).

Each plant species has particular habitat requirements which can be defined by a number of different attributes, such as those defined by Grime (2001) and Ellenberg et al. (1991). The habitats where the larval foodplants grow define one of the locations where the adult butterflies are likely to be found, although of course they do utilise other habitats as well, such as for feeding, mate location, roosting hibernation, and predator escape (Dennis et al. 2003).

Accurate lists of larval foodplants are important to ensure where limited conservation resources are best directed. Many publications of European butterflies (e.g., Tolman and Lewington 2008; Tshikolovets 2011 and Leraut 2016) provide lists of the larval foodplants for each species. These lists have typically been copied from previous lists, which in turn have been copied from earlier lists. This has resulted in typographical errors creeping in, and mistakes being perpetuated. Many of the plant names are now out of date, and were considered synonyms even when Flora Europaea (Tutin et al. 1993, 1968, 1972, 1976, 1980) was published. In addition, contrary to best practice, only the binomial is provided without the authority, which can lead to confusion as to which species is being referred to. In the World Checklist of Vascular Plants (WCVP 2021) there are 40 entries for the species *Centaurea paniculata*, which refer to thirteen different accepted species, depending on authors, subspecies, varity or form.

Middleton-Welling et al. (2020) provide a reliable database on the life history traits of European butterflies, which include a measure of larval host specificity. Whilst a number of traits for larval hostplants are provided, the authors do not provide any specific reference for the larval hostplants used by European butterflies. Here, a new checklist of the currently accepted names of the larval foodplants of the European butterflies has been created. Wiemers et al. (2018) has been used to define the list of European butterflies.

Methods

Tshikolovets (2011) was used to create an initial list of larval foodplants. Tolman and Lewington (2008) was used as a basis for the larval foodplants of *Aporia crataegi*, and to update the list where only the generic name was given. Lepiforum (2021) was used for the larval foodplants of *Pieris rapae*. The plant list and references within van Oorschot and Coutsis (2014) were used for the genus *Melitaea*. Google Scholar was then used to search for references for the larval foodplants for all butterfly species, using the initial plant list to aid searching. Google Translate was used to help in the interpretation of literature where required. The HOSTS database (Robinson et al. 2010) was not used as a source of information as it contained some questionable records for European butterflies, and does not include references.

Where possible, primary sources were used, where the author(s) had found larvae in the wild using particular plants. Plants used in breeding experiments were ignored, unless there was evidence the plant was actually used in the wild. Secondary sources were used where for practical reasons (unavailability or cost) it was not possible to easily obtain the primary reference. Where there was evidence that entries in the initial list were incorrect, those entries were deleted. The aim was to create a list of larval foodplants that were used in the wild by European butterflies, from the state of current knowledge from the searched resources.

As many of the plant names are not the currently accepted names, the following procedure was used to update the plant names, using the World Checklist of Vascular Plants version 4 (WCVP 2021) as the list of accepted plant names.

- The online resources of Plants of the World Online (https://powo.science.kew.org/), World Checklist of Vascular Plants (WCVP 2021) and GBIF (https://www.gbif.org/) to help identify the accepted name.
- The plant name is an accepted taxonomic name in the WCVP list. For example, *Lonicera xylosteum* L., rather than any of the other synonyms of the species.

- The plant name is a synonym or homotypic synonym of an accepted name in the WCVP list.
- The plant name had several taxonomic names in the WCVP list with different authors, with the author defined in Flora Europaea giving the definitive plant name.
- The plant name was not in the WCVP list, but was defined as a synonym in Flora Europaea of a plant name in WCVP.
- The plant name was not in WCVP nor Flora Europaea, but was found online as a synonym of an accepted name in WCVP or another list.
- The plant name was not in WCVP nor Flora Europaea, but an online search suggested a typographical error for a different genus, which could be confirmed by checks with other sources, such as Tolman and Lewington (2008).
- The plant name was not in WCVP nor Flora Europaea, and could not be identified by an online search. In these cases, the plant was ignored.

A database table was created containing the accepted plant with the butterflies' larvae that utilise that plant. A constraint was placed on the table to ensure that duplicates could not be entered, such as when a plant in the original list contained both an accepted name and a synonym.

Butterflies that have a predominantly African distribution, and with a very limited European distribution, were checked as to which plants they utilised in Europe and the European islands of Macaronesia (i.e., not Cape Verde islands).

Butterfly subspecies outside of Europe have been ignored. Otherwise butterflies are only treated at the species level. It is unknown whether any butterfly species are specific to a particular plant subspecies. It has been assumed that butterfly larvae are able to utilise all the subspecies of a plant that are found within their distribution. Consequently, plant subspecies have been ignored, and plants are only treated at the species level. Checks were made that the subspecies was not now considered another species.

Larval hostplants that are unknown at species level are recorded at the generic level where known. Information from breeding experiments is only used where no other information is available and stated in the results section.

The list of larval foodplants has been brought up to date with the current accepted plant names, thus plant species with several different names have been reduced to having just one name; the currently accepted name. Plants that could not be identified, or were identified as having a distribution outside of Europe were excluded. Errors where identified have been removed. This has resulted in an initial list of 1977 European butterfly larvae-hostplant relationships, being doubled to 4080.

The references list the sources used to produce the list of larval foodplants used by European butterflies, and are cited in the Suppl. material 1. Where there were multiple references for a particular larval foodplant, usually the first found was used as the reference. No particular significance should therefore be given to the reference provided, as no attempt was made to use the best reference, or the earliest reference. However, if a particular useful source was found that described the complete life-cycle, an attempt was made to include it in the set of references for a particular butterfly species.

The quality of the references varies greatly with regards the evidence provided that that particular plant is used by that butterfly larvae. Consequently, it is virtually impossible to verify the information provided, other than by another source providing the same information. Many plants are difficult, if not impossible to accurately identify in their vegetative state, requiring flowers and/or fruits/seeds for accurate identification.

In some cases, the plant name provided by a reference was ambiguous, as the authority was not specified. Sometimes this ambiguity could be resolved by the distribution, but in other cases, there were other hostplants with the same distribution. For example, in Reinhardt et al. (2020), *Vicia angustifolia* is given as a larval foodplant for *Leptidea sinapis*, which could be one of three accepted species *V. lathyroides*, *V. sativa*, or *V. setifolia*. As the latter is South American it can be ruled out, but the other two species have European distributionx. Without knowing the authority of *V. angustifolia*, it is impossible to know which species is being referred to, and consequently it was not possible to include that plant in the list from that source.

A comprehensive search of all synonyms was not made, so some references may have been missed. Some potential references could not be checked as they were not easily accessible (due to unavailability or cost).

Results

The discovery of new cryptic butterfly species, such as the separation of *Polyommatus icarus* and *P. celina* can cause problems in understanding their larval foodplants. Larval foodplants have been assigned where identification is confirmed, although records referenced by Tshikolovets (2011) need to be confirmed. For allopatric species, such as *Euchloe ausonia* and *E. crameri*, their larval foodplants were identified based on the distributions of both species, provided that regional plant lists are available. However, for sympatric species such as *Leptidea juvernica*, *L. sinapis* and *L. reali*, larval foodplants could apply to all, some or to only one species. A re-survey of the larval foodplants is required. Where there are morphological differences between the larvae, such as for the post diapause larvae of *Melitaea ornata* and *M. phoebe*, the identification can be confirmed in the field.

Recent research suggests that *Muschampia proto* should be split into three species (Hinojosa 2021), *Zegris eupheme* should be split into two species (Back 2012, 2020), and *Hyponephele lupina* should be split into two species (Lukhtanov 2021). Given that the distributions of these species are allopatric, references have been provided for each of the regions, which will provide larval lists for these new species if the splits are generally accepted.

The larval foodplants are still unknown for the following 25 European butterfly species: *Erebia dabanensis*, *Erebia edda*, *Erebia gorgone*, *Erebia jeniseiensis*, *Erebia orientalis*, *Hipparchia blachieri*, *Hipparchia christenseni*, *Hipparchia cretica*, *Hipparchia cypriensis*, *Hipparchia mersina*, *Hipparchia pellucida*, *Hyponephele huebneri*, *Issoria eugenia*, *Maniola chia*, *Maniola cypricola*, *Maniola halicarnassus*, *Maniola megala*, *Oeneis ammon*, *Pieris balcana*, *Polyommatus timfristos*, *Pseudochazara anthelea*, *Pseudochazara graeca*, *Pseudochazara mercurius*, *Pseudochazara orestes* and *Thymelicus christi*.

Of the 471 European butterfly species where the larval foodplants are known, 1506 different plant species are utilised in 72 families, of which 86 records have only been identified to generic level in 40 different genera (mostly grasses). For each plant, the family and order have been specified. The full scientific names are provided in the Suppl. material 1 (European_butterfly_larval_foodplants.xlsx).

The only information about larval foodplants for the five endemic Canary Island Graylings (*Hipparchia tamadabae*, *H. wyssii*, *H. tilosi*, *H. bacchus* and *H. gomera*) is available from breeding experiments by Jutzeler et al. (2007). This single grass has been included in the list of larval foodplants, although its use in the wild does need to be confirmed.

Where it was not possible to identify the accepted plant name in the WCVP list, or using other resources such as GBIF, the Royal Botanic Gardens, Kew was consulted as to the current accepted name. Four plants were thus added to the WCVP list:

- *Rosa agrestis* × *micrantha* – this is a natural hybrid between *Rosa agrestis* and *Rosa micrantha*
- *Achnatherum parviflorum* – this is the accepted name in the World Checklist of Selected Plant Families (WCSP 2021). It was previously known as *Stipa parviflorum*.
- *Goniolimon cuspidatum* – this is the accepted name in the World Flora Online (WFO 2021)
- *Alpagrostis setacea* – this is the accepted name in the online version of WCVP (2021).

The family Adoxaceae defined in APG4 is considered a synonym for Viburnaceae by Plants of the World Online (PWO 2021), and Viburnaceae is the name used by WCVP.

Most plant families are utilised by less than six butterfly species; however a few plant families are particularly favoured by butterfly larvae, with the Poaceae and Fabaceae being the most used (Table 1).

Table 1. Top ten most used plant families.

Plant family	No. of butterfly species
Poaceae	150
Fabaceae	93
Rosaceae	52
Cyperaceae	45
Brassicaceae	31
Polygonaceae	27
Lamiaceae	24
Plantaginaceae	21
Violaceae	21
Ericaceae	19

Most plant species are only utilised by one or two species; however, a few plant species are particularly well-used by butterfly larvae, with *Festuca ovina* and *Festuca rubra* being the most commonly so (Table 2).

Table 2. The most used plant species.

Plant	No. of butterfly species
Festuca ovina	68
Festuca rubra	40
Poa annua	39
Brachypodium pinnatum	36
Dactylis glomerata	29
Bromus erectus	27
Deschampsia cespitosa	24
Brachypodium sylvaticum	22
Brachypodium phoenicoides	21
Lotus corniculatus	21
Nardus stricta	21

Of the 471 butterfly species, over half (255) utilise five or less larval foodplants, of which 92 species are monophagous. Whilst 2.5% utilise 48 or more different larval foodplants, with *Pieris rapae* using 82 different larval foodplants in Europe and *Vanessa cardui* using 77.

70% (331) of European butterfly larvae utilise just one plant family, with a further 18% (84) butterfly species using two plant families, and 29 butterfly species using three plant families. The butterfly species utilising the most different plant families is *Celastrina argiolus* (Table 3).

Table 3. Butterfly species utilising the most plant families.

Butterfly name	No. of plant families.
Celastrina argiolus	19
Euphydryas maturna	10
Callophrys rubi	9
Leptotes pirithous	8
Charaxes jasius	7
Nymphalis vaualbum	7
Polygonia c-album	7
Vanessa cardui	7

Discussion

Butterflies can be classified according to the larval foodplants that they utilise into four main types (Courtney 1984):

- Monophagous feeding on only one species of plant throughout their range.
- Oligophagous-monophagous (OM) – feeding on one plant species in one region, and another species in another region.
- Oligophagous-polyphagous (OP) – feeding on several closely related species of plant throughout their range, usually in the same genus, or a closely related genus.
- Polyphagous – feeding on many different species of plants throughout their range, usually in different families.

The larvae of many butterfly species are oligophagous, feeding on a few species of plants. These can fall into two groups, those that use only one species of plant per habitat, and those that use multiple species of plant per habitat (Wiklund and Åhrberg 1978). This can mean that larvae change their foodplant(s) in different regions.

A list of plant species does not distinguish between OM and OP type butterfly species. Regional lists of plants, such as those produced by Munguira et al. (1997) are useful. Additionally, a list of plant species does not provide information on plant suitability for high larval survivability. Preferences for larval foodplants are largely unknown for oligophagous and polyphagous butterflies, expect in a few cases. This is an important consideration when considering conservation efforts, which should be directed towards the primary larval foodplants for the region, rather than for plants that are only exceptionally used. For example, the main larval foodplant of *Aglais urticae* is *Urtica dioica*, although it will occasionally use other plants. The chemical constitution of the foodplant would be appear to be of prime importance in the development of the larvae (Feltwell 1982). Experimental evidence has shown that different foodplants have different effects on the growth of

the larvae (Feltwell1982). The survivability of larvae on different plants is largely unknown except in a few cases where the butterfly species has been studied in detail.

It is common for butterfly species to oviposit off the larval foodplant (Singer 1984). Where butterflies lay their eggs is dependent on their life-cycle and plant abundance (Wiklund 1984). Species of the Satyrinae are more likely to lay their eggs off-host. For species that overwinter as eggs, those that use herbaceous plants are more likely lay their eggs off-host, whereas those species that use woody plants lay their eggs on the host. For example, *Argynnis paphia* oviposits on tree trunks above where *Viola* spp. are growing. *Thecla betulae* oviposits on *Prunus spinosa*, although mistakes are made, as I have found *Thecla betulae* eggs on *Crataegus monogyna*, whilst searching for eggs on *Prunus spinosa*, probably due to the overlapping branches of the two shrubs in this location. However, two references were found for *T. betulae* using *C. monogyna* (de Tré 1987; Ţugulea et al. 2016). In any case, it was not clear from these sources whether larvae were actually using *C. monogyna.*

The checklist of larval foodplants presented here no doubt contains errors. The main reasons for errors are incomplete documented evidence of hostplant usage. Mistakes have been made in the identification of the larvae and/or the plant being utilised. Assumptions may be made that the butterfly utilises a particular plant that is widespread in the areas where it is found, whereas in reality it utilises another plant. Sometimes the plant authority was wrong. For example, *Bromus erectus* has been specified, in cases where *Bromus erectus* Huds. is an accepted name, or *Bromus erectus* Moris was meant, which is a synonym of *Bromus scoparius* L. Both plants share a distribution in southern Europe. Oviposition evidence does not proof that larvae can complete their development on that plant, as many butterflies oviposit off-host.

Conclusions

Future publications should ensure that old and ambiguous plant names are not used. Plant names should be specified with their full scientific name, as specified by the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018). The World Checklist of Vascular Plants (WCVP) should be checked to ensure the currently accepted plant name is being used.

Fully documented records are required of what larval foodplants butterfly larvae are utilising in the wild. To get a better understanding of usage, full details need to be recorded, including, date, location, altitude, abundance, and larval stage. Abundance will help in the understanding of preferences. To enable records to be properly verified, evidence should be provided on how larvae and plants were identified. Regional lists are also important, to help direct conservation efforts to the plants being used locally, rather than elsewhere.

This list of larval foodplants is provided as a step towards a fully justified database, which will be updated as and when corrections are found. It highlights those 25 butterfly species whose larval foodplants are currently unknown.

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Supplementary material 1

Table S1

Authors: Harry E. Clarke

Data type: Excel spreadsheet.

Explanation note: Checklist of the accepted names of larval foordplants of European Butterflies.

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